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(71) Applicant *(for all designated States except US)*: MECEL AB [SE/SE]; P.O. Box 73, S-662 22 Åmål (SE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: JOHANSSON, Hans [SE/SE]; Kompassgatan 12, S-662 36 Åmål (SE). NYTOMT, Jan [SE/SE]; PL 1658, S-662 01 Åmål (SE).

(74) Agent: FURHEM, Hans; Mecel AB, P.O. Box 73, S-662 22 Åmål (SE).

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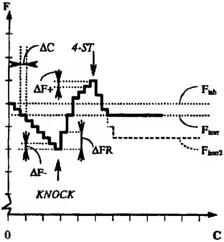
(57) Abstract



The invention relates to a method and system for adaptive correction of the amount of fuel supplied in two-stroke combustion engines. During a continuous operation period is the air-fuel mixture regulated by force in increments in the lean direction (ΔF^-) respectively in the rich direction (ΔF^+), whereby the fuel amounts (F) could be established which causes knocking (KNOCK) respectively four-stroking or misfiring (4-ST). These limit values are stored as a lean limit value M_{FK} respectively a rich limit value M_{F4ST}. For further operation of the combustion engine is a corrected fuel amount F_{korr}, used, which is corrected in relation to the fuel amount F_{tab} given from an empirically determined value stored in a map, and dependent of the established lean limit value M_{FK} respectively the rich limit value M_{F4ST}. The fuel amount (F) supplied will suitably be given according the function: $F = F_{korr} = M_{FK} + K \cdot (M_{F4ST} - M_{FK})$, where K is a margin factor which defines if further operation of the engine will be controlled having an equidistant margin towards a knocking condition respectively a four-stroking or misfire condition, if K is set to a value of 0.5, or if further operation will be controlled toward leaner air-fuel ratios, if K is set to a value below 0.5. Further control could thus be made having a fixed relative margin towards a knocking condition as well as a four-stroking condition.

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METHOD AND SYSTEM FOR AN ADAPTIVE FUEL CONTROL IN TWO-STROKE ENGINES

Present invention relates to a method for fuel control in two-stroke engines according the preamble of claim 1, and a system used for the performance of the method according the preamble of claim 10.

PRIOR ART

For larger combustion engines in vehicles are used relatively complicated systems in order to reduce emission levels and fuel consumption. A feedback system having a lambda sensor in the exhaust system, is often used. The lambda sensor is used to control that the proper air-fuel ratio is maintained, whereby a three-way catalytic reactor could operate at optimum efficiency.

For smaller and less expensive two-stroke engines, for example used in hand held garden machines, it becomes considerably more difficult to obtain a control system that will not dramatically affect the cost for the propulsion unit. Control systems with lambda sensors are comparatively expensive, and the lambda sensor is sensitive to fuel contamination. The major problem in two-stroke engines is that relatively large amounts of unburned hydrocarbons are exhausted. This is caused by the two-stroke engines having rather simple type of control systems, and often optimised for driveability at the expense of increased content of hydrocarbons in the exhaust. Controlling air-fuel ratios in the lean direction often results in reduction of unburned hydrocarbons in the exhaust. At the same time will driveability decrease when controlling in the lean direction, and the risk for engine damages increases.

In control systems where the control in the lean direction only is made towards the knock limit, in order to reduce emissions, is a knocking condition ceased by increasing the fuel amount. The increase of the fuel amount could in certain operating cases come close to or exceed the amount of fuel that cause a four-stroking condition.

OBJECT OF THE INVENTION

An object of the invention is to obtain an optimal control of a two-stroke combustion engine as of the amount of fuel supplied. The optimal amount of fuel supplied is adapted to the fuel quality, the temperature of the combustion engine and the condition of the spark plug.
Another object is to obtain an adaptive control system for two-stroke engines, which control system on a regular basis could establish feedback reference signals regarding the extreme limits for lean- and rich air-fuel ratios.
Yet another object is that the performance of control of the combustion engine could be based upon feedback information representative for the air-fuel ratio A/F, without using lambda sensors. A cost

efficient and inexpensive control system could thus be construed and implemented also for smaller two-stroke engines without increasing the cost dramatically for such engines.

Yet another object is to obtain a reduction of unburned hydrocarbons in the exhaust from two-stroke engines, which also will cause reduction of the fuel consumption, while maintaining driveability at an optimal high level at the prevailing conditions.

SHORT DESCRIPTION OF THE INVENTION

The inventive method is characterised by the characterising clause of claim 1, and the system for the performance of the inventive method is characterised by the characterising clause of claim 10.

By the inventive method and the system for the performance of the method could optimal driveability be obtained as well as minimised levels of hydrocarbon emissions and fuel consumption. Driveability increases up until a certain limit of rich air-fuel ratio, while the emission levels decreases at leaner air-fuel ratios. By establishment of the rich limit of the air-fuel mixture, causing four-stroking of the engine, and the lean limit of the air-fuel ratio, causing a knocking condition in the engine, could the optimal amount of fuel be established. The optimal amount of fuel could then be determined having predetermined margins towards the four-stroking limit as well as towards the knocking limit. This is advantageous for combustion engines operating with different qualities of fuel, and different types of ignition plugs, ignition gaps and varying ambient temperatures, etc. These different conditions of operation could lead to that the possible control range of the fuel amount supplied, ranging from a lower amount of fuel causing a knocking condition to a larger amount of fuel causing a four-stroking condition, could show considerable differences in the size of the control range. The control according the inventive method will maintain a constant relative margin towards a knocking condition as well as a four-stroking or misfire condition, irrespective of the size of the possible control range.

Other distinguishing features and advantages will appear from the characterising clauses of the remaining claims and the following description of preferred embodiments. The descriptions of preferred embodiments are made by reference to the figures specified in the following list of figures.

FIGURES

Figure 1 shows how the amount of fuel by forced control in steps $\Delta F/\Delta F^{*}/\Delta FR$ is controlled to a knocking condition KNOCK, respectively a four-stroking condition 4-ST,

Figure 2 shows a flow-chart for the inventive method,

Figure 3 shows schematically a system used for the performance of the inventive method.

DESCRIPTION OF EXEMPLARY EMBODIMENTS.

In figure 1 is shown how the amount of fuel F supplied, is controlled according the inventive method, which method more closely is described by reference to the flow-chart shown in figure 2.

In figure 1 is the order of combustion C specified at the horizontal X-axis, and at the vertical Y-axis is specified the present amount of fuel supplied. At the starting point, which corresponds to the step 20 in figure 2 and the combustion of order 0 at the X-axis in figure 1, is a fuel amount F_{ub} supplied, given by a stored fuel map or table established from and dependent of detected engine parameters. The fuel map is in a conventionally manner an empirically established map, where the map for each type of engine and application is established from extensive tests.

The method will proceed to step 22 when a substantially constant load case, so called steady state, is detected in step 21. A steady state is defined by the engine not being subjected to a transient load case, such as acceleration or pulsating load. In step 22 the present amount of fuel F supplied will be set to the fuel amount F_{ub} given by the map. The constant load case could be considered as a prevailing condition when speed- and load fluctuations are within predetermined limits, preferably less than 5-10% of the present speed or load. The start is thus dependent of prevailing conditions, i.e. that a substantially constant load case exist.

A reduction of the amount of fuel supplied is thereafter made with a predetermined increment ΔF^-. After having supplied the reduced amount of fuel a control is made in step 24 if a knocking condition has occurred due to the reduction. The knocking condition is an uncontrolled combustion that could be detected by vibration sensitive sensors mounted at the engine block or by analysing the ionisation current in the combustion chamber with a detection circuit similar to the circuit shown in EP,B,188180. On the other hand it is desirable in certain type of applications, where emissions and fuel consumption are considered, to lie as close as possible to the knock limit, but at a safe distance thereof. An optimal lean air-fuel ratio will thus be obtained, without running a risk of a knocking condition appearing, which is damaging to the engine.

If a knocking condition is not detected in step 24, the programme will proceed to step 25 wherein a hold parameter C is updated at each execution of step 25. The hold parameter C could preferably correspond to one power stroke of the combustion engine, in such a way that for each ignition is the hold parameter C added by a value of 1. A control is thereafter made in step 26 if the hold parameter have reached a predetermined number ΔC of power strokes, and as long as this number of power strokes has not been performed will the program return to step 25. The hold loop 25-26 will thus lead to that the reduced amount of fuel will be supplied during a number of combustion's dependent of the predetermined factor ΔC, whereby any dynamically induced effects from the reduction could attenuate properly. ΔC is preferably set to a couple of tens of power strokes.

After the hold loop 25-26 having supplied the present reduced amount of fuel for a number ΔC of power strokes, then the programme will return to step 23 where a further reduction of the amount of fuel supplied is made with the predetermined increment ΔF^-. The steps 23-26 will consequently be repeated while successively reducing the amount of fuel supplied by the predetermined increment ΔF^-, which each reduced amount of fuel is supplied for a number ΔC of power strokes.

When a knocking condition is detected in step 24, which knocking condition(KNOCK) in figure 1 occurs after 8 successive reductions of the empirically determined amount of fuel F_{tab}, by the increment ΔF^-, is the successive reduction of fuel interrupted and the programme proceeds to step 27. In step 27 is the present fuel amount F supplied stored in a memory M_{FK}, which amount of fuel is the lean amount of fuel which will develop a knocking condition. M_{FK} is hereafter designated as the lean limit value.

The programme will thereafter proceed to step 28 where the fuel amount supplied will be returned to the fuel amount F_{tab} as given by the map. The return sequence is preferably performed in steps having a predetermined increment ΔFR, in order not to cause sudden changes between an extreme lean operation and the empirically determined ideal operation as given by the stored map. The return sequence will thus be obtained in a successively manner until the present amount of fuel supplied corresponds to the fuel amount F_{tab} given by the stored map.

The successive return sequences do not necessarily have to be as lengthy as the successive reduction in the lean direction towards the knocking limit, as caused by the hold loop 25-26. The return sequence is performed towards an ideal condition and not towards an extreme condition having a lean limit air-fuel ratio where an exact determination of the lean limit value is desired. The return sequence from a knocking condition (KNOCK) could thus be performed by increasing the amount of fuel supplied with the increment ΔFR for each successive combustion, as shown in figure 1.

As could be seen in figure 1 is ΔF^- smaller than ΔFR, which is the most advantageous implementation, by which the knocking limit will be approached in a cautious manner in order to obtain a proper establishment of the lean limit value M_{FK}, while the return sequence could be performed as quick as possible but nevertheless obtaining a smooth control of the engine.

When the return sequence have reached the fuel amount F_{tab} given by the map, which is detected in step 29, then the programme proceeds to step 30 where the fuel amount F supplied is increased by a predetermined incrementΔF^+. During a gradual control in the rich direction of the air-fuel ratio, one will finally reach a condition where the engine starts to misfire, or if it is a two-stroke engine the engine will start a four-stroking process, i.e. only ignite after every second compression phase.

After the supply of the increased amount of fuel a control is made in step 31 if the increases have induced a misfire or a four-stroking (4-ST) condition. Misfire or a four-stroking condition could be

detected in a similarly manner as the knocking condition by analysing the ionisation current in the combustion chamber with a detection circuit similar to the circuit shown in EP,B,188180. No ionisation current will be developed during a misfire.

If a misfire or four-stroking condition is not detected in step 31 then the programme will proceed to a hold loop 32-33 corresponding to the hold loop 25-26. The hold parameter C and the predetermined hold factor ΔC are preferably identical in the hold loop 25-26 respectively in the hold loop 32-33. In a similar manner will the increased amount of fuel be supplied during a number of combustion's dependent of the predetermined factor ΔC, whereby any dynamically induced effects from the increase could attenuate properly.

After the hold loop 32-33 having supplied the present increased amount of fuel for a number ΔC of combustion's, then the programme will return to step 30 where a further increase of the amount of fuel supplied is made with the predetermined increment ΔF^+, which each successively increased amount of fuel is supplied for a number ΔC of combustion's.

When a misfire or four-stroking condition is detected in step 31, is the successive increase of fuel interrupted and the programme proceeds to step 34. In step 34 is the present fuel amount F supplied stored in a memory M_{F4ST}, which amount of fuel is the rich amount of fuel which will develop a misfire or four-stroking condition. M_{F4ST} is hereafter designated as the rich limit value.

At this stage has a lean limit value M_{FK} as well as a rich limit value M_{F4ST} been stored in memories.

A numerical calculation of a corrected optimal amount of fuel F_{korr} could then be performed. The corrected amount of fuel F_{korr} could be adapted to the prevailing operating conditions, in such a manner that safe and secure margins are obtained in relation to a knocking condition or a misfiring or four-stroking condition.

The programme proceeds to step 35 where this calculation of F_{korr} is performed. F_{korr} could preferably be calculated by adding up the lean limit value M_{FK} with a part of the difference between the rich limit value M_{F4ST} and the lean limit value M_{FK}. Said part of the difference being obtained by multiplying the difference with a predetermined margin factor K, according;

$$F_{korr} = M_{FK} + K \cdot (M_{F4ST} - M_{FK})$$

The margin factor K could for each type of application or engine be selected according the determining criteria's for the functionality of the engine. If for example an optimal margin in relation to a knocking condition as well as misfiring condition is desirable, could the margin factor be set to 0.5. A margin factor of 0.5 will give a fuel amount F_{korr} according figure 1, in relation to the lean limit value M_{FK} and the rich limit value M_{F4ST}. The fuel amount is here half-way between the lean limit value M_{FK} and the rich limit value M_{F4ST}.

If instead an optimal lean air-fuel ratio is desired, which could be desirable if harsh emission demands are made for the combustion engine, could instead the margin factor be set to a value in the

range 0.15-0.20. A margin factor in the range 0.15-0.20 will give a fuel amount F_{korr2} according figure 1, in relation to the lean limit value M_{FK} and the rich limit value M_{F4ST}. The fuel amount F_{korr2} is here slightly above the lean limit value, 15-20 % of the difference between the rich limit value M_{F4ST} and the lean limit value M_{FK}

The margin factor K could also be a variable factor dependent of engine parameters, for example dependent of engine temperature $K(t_m)$, or engine temperature and inlet air temperature $K(t_m, t_i)$.

After having calculated the corrected amount of fuel F_{korr} in step 35, then the programme proceeds to step 36, where a return sequence is initiated which will adjust the fuel amount supplied to the corrected amount of fuel F_{korr}. The return sequence is preferably performed in steps having a predetermined increment ΔFR, in a similarly manner as performed in the return sequence in steps' 28-29. Detection is made in step 37 if the amount of fuel supplied have reached the corrected amount of fuel. As long as this corrected amount of fuel has not been reached will a reduction of the amount of fuel supplied be made with the increment ΔFR, and possibly reduced for each successive combustion.

When the amount of fuel supplied corresponds to the corrected amount of fuel F_{korr}, as established from the detected rich limit value and the lean limit value, then the programme in step 38 will return to the main programme. The set value stored in the map could possibly be corrected in the main programme, or alternatively could a correction factor K_F be stored and established according;

$$K_F = F_{korr} / F_{tab}$$

The correction factor K_F could thereafter be used for the entire map, for each fuel amount in question given by the map, irrespective of changes in speed or load. In an alternative mode of operation could a number of correction factors be established for several different combinations of speed and load, where correction factors for speed and load cases in between are established by linear interpolation. The correction factor K_F could in a similarly manner as the margin factor K be dependent of engine temperature and possibly also the inlet air temperature, as $K_f(t_m, t_i)$.

In figure 2 is the loop 25-26 as well as the loop 32-33 also shown in a modified alternative embodiment, relating to updating of the hold parameter C. The programme could preferably return to step 24 respectively step 31 after each update of the hold parameter C. This procedure would enable detection of a knocking condition respectively misfiring or four-stroking condition occurring during the time when the latest execution of reduction or increase of the fuel amount is allowed to come into effect. This alternative is shown by dotted flow arrows. In this manner is a further reduction or increase of the fuel amount avoided, if a knocking or four-stroking condition occurs during the updating sequence of the hold parameter to the value ΔC.

The hold parameter is set to a zero value preferably automatically at each start of the main programme, and when the hold factor ΔC in steps 26 respectively 33 have been reached.

Establishment of the rich limit value M_{FAST} and the lean limit value M_{FX} is made repeatedly during one and the same continuos operating period of the engine. The repetition rate is determined by a predetermined function that will restrict the number of occasions when this establishment is made over a time period. The establishment of the values should only occur during fractions of the total operating time of the engine. Said fraction being less than 5% of the total operating time, and preferably no more than 1% of the total operating time. A control could be made in step 21 for this purpose, where a control is made if a certain time T have elapsed since the latest establishment of the corrected fuel amount F_{korr}. The step 21 contains a two-part condition, a load condition and a time condition, where both of these conditions must be fulfilled before a new establishment of F_{korr} is made. In this way is assured that the engine is not frequently forced away from ideal operating conditions. This is advantageous for hand-held two-stroke engines, which often are operating over longer time intervals at a substantially constant load case. When a two-stroke engine has reached normal operating temperature, then the operating conditions usually only changes after a comparatively long time period. This will lead to that a new establishment of F_{korr} only needs to be performed after very long intervals.

During the warm up period of the combustion engine, or whenever dT/dt, preferably the first order derivative of the engine temperature, have a comparatively high value, is a new establishment of F_{korr} performed at shorter intervals. The predetermined time T in step 21 could be dependent of the temperature $T(m_i)$ in such a way that T is set to very short time value until the engine reaches its normal operating temperature. The time T could possibly assume successively longer time values as the engine temperature approaches the normal operating temperature.

In figure 3 is shown a system used for the performance of the method according claim 1. The combustion engine is here shown having four cylinders 6, but engines having different number of cylinders could be used. A number of engine parameters EP such as speed, load and engine temperature are detected with a number of sensors mounted on the engine.

The combustion engine, preferably a Otto-engine, is here equipped with an ignition system having a microcomputer controlled ignition control unit 2 and at least one spark plug for each cylinder. The ignition spark in the ignition plug is generated in a conventionally manner by the ignition control unit 2 and an ignition coil 7 where the ignition voltage is induced. The ignition coil could be a common coil for all of or a part of the spark plugs in the engine. A system corresponding to the system shown in EP,B,188180 is preferably used, having an ignition coil mounted on top of each ignition plug without any ignition cables between the ignition coil and the spark plug. The ignition timing is

conveniently obtained in a conventionally manner from a map contained in the ignition control unit 2. The ignition timing obtained from the map is set to a crankshaft position before the upper dead centre, dependent of the detected engine parameters EP.

The combustion engine is furthermore equipped with a microcomputer controlled fuel control unit 8 having preferably one fuel injector nozzle 8 for each cylinder 6. The amount of fuel supplied is controlled by the fuel control unit 3, sending a pulse to an electrically controlled valve, possibly an electromagnetic valve, included in the injector 8. The pulse width corresponds to the amount of fuel supplied. At least one injector is preferably used for each cylinder, a so called multi-point injection system. A common injector for all cylinders, a so called single point injection system, could alternatively be used. Determination of the pulse width, i.e. the amount of fuel supplied, is preferably performed in a conventionally manner by the fuel control unit 3. The pulse width is obtained from an empirically established map stored in the fuel control unit, where the necessary pulse width is dependent of the detected engine parameters EP. The map F=f(EP) from which the necessary amount of fuel is obtained, i.e. pulse width, is stored in a part 5A of a memory 5 of the fuel control unit 3.

The fuel control unit 3 also obtains information regarding a misfiring or four-stroking condition and a knocking condition at input data lines 10 respectively 11. In the preferred embodiment is a misfiring condition as well as a knocking condition detected by the ignition system 2, which measure the ionisation current in the spark plug gap using an arrangement as shown in EP,B,188180. No additional sensors are thus needed, such as vibration sensitive sensors mounted on the engine block(for detection of a knocking condition) or sensors for detection of misfiring conditions.

A misfire condition could be detected using different methods, which for example could use pressure sensors arranged in the combustion chamber or by using different types of circuitry or software capable of detecting crankshaft speed irregularities.

The memory of the fuel control unit also includes memory locations 5b and 5c, for a temporary storage of the lean limit value M_{FK} respectively the rich limit value M_{F4ST}. The different parameters C, ΔC, the margin factor K, the correction factor K_F and the control increments ΔF^+, ΔF^-, ΔFR are also stored in the memory. The control increments ΔF^+, ΔF^-, ΔFR and C, ΔC are preferably stored in the memory as fixed and non erasable predetermined constants, preferably a memory location of a PROM-type. M_{FK}, M_{F4ST}, the margin factor K and the correction factor K_F are preferably stored in an alterable but volatile part of the memory, which could be a RAM-type of memory. These volatile parameters will thus disappear each time the control system is deactivated. At each start up will the control commence with the non-corrected parameters obtained from the map. A new establishment of M_{FK}. M_{F4ST}, the margin factor K and the correction factor K_F will be made after each start-up.

In this way is a new correction scheme implemented at each start-up. This could be motivated for example if refuelling have been made of a different fuel quality, or if the engine temperature changes or if the gap size in the spark plug gap is altered.

In an alternative embodiment could at least the margin factor K and/or the correction factor K_F, which factors have been established from limit values M_{FK} and M_{F4ST} obtained from a preceding operation period, be stored in alterable but non-volatile memories. At each start up will the fuel control commence with fuel amounts corrected by these factors, and following determinations of M_{FK} and M_{F4ST} could establish new factors K respectively K_F.

The four-stroking condition as well as a knocking condition is both preferably detected using the spark plug. The ionisation current in the spark plug gap could be analysed in a measuring window open during the post ionisation phase that follows the ignition voltage break down phase. A knocking condition could be detected by filtering out a characteristic frequency content, representative for a knocking phenomenon, from the ionisation current during the post ionisation phase. A four-stroking or misfiring condition could be detected from the ionisation current, by the fact that no ionisation current will be developed during a misfire event. A circuitry integrated in the ignition system corresponding to the circuitry shown in EP,B,188180, could in this respect be implemented. Rather modest additional costs are incurred for the ignition system in question, essentially caused by some minor circuits having a limited number of for this purpose necessary discrete type of electronic components.

The invention could be modified in a number of embodiments beyond the embodiment shown. For example could the rich limit sequence be initiated before the lean limit sequence, i.e. the rich limit value is determined before the lean limit value.When the present range between the lean limit value and the rich limit value once have been determined, could subsequent control be performed where only the lean limit value is updated, or that the rich limit value is updated at considerably longer intervals. The increment ΔFR used in the return sequence do not necessarily have to be performed in discrete steps dependent of the occurrence of a number of combustion's. The return sequence could instead be executed as a time dependent function, for example in such a way that the return sequence is performed as a linear control over a time period. If the determination of the lean limit value and the rich limit value should be made as fast as possible, at the expense of a smooth control of the engine, could the return sequence to the set value of the map respectively the corrected value F_{korr} be made in one single step. The hold parameter C could instead of a number of combustion's correspond to a time period, where the factor ΔC corresponds to a predetermined or speed dependent time period, during which the latest initiated reduction or increase of the fuel amount should be allowed to come into effect, before the next reduction or increase of the fuel amount is initiated.

The empirically determined amount of fuel could instead from a map be given from a neural net, which neural net has been trained to give the desired output signal, i.e. fuel amount, dependent of the engine parameters detected.

CLAIMS

1. Method for fuel control in two-stroke combustion engines c h a r a c t e r i s e d i n -that an empirically determined fuel amount (F_{ub}) is supplied to the engine dependent of detected engine parameters such as speed and load,
- that a gradual reduction (ΔF^-) in the lean direction of the empirically determined amount of fuel (F_{ub}) is made until a uncontrolled combustion occurs, i.e. a knocking condition, and that a lean limit value (M_{FK}) corresponding to the reduced amount of fuel momentarily supplied when the knocking condition occurs is stored in a memory,
- that a gradual increase in the rich direction of the empirically determined amount of fuel (F_{ub}) is made until the two-stroke engine starts four-stroking due to misfire, and that a rich limit value (M_{F4ST}) corresponding to the increased amount of fuel momentarily supplied when the four-stroking condition occurs is stored in a memory,
-and when the rich limit value (M_{F4ST}) and the lean limit value (M_{FK}) have been stored is an adaptive set value (F_{korr}) for the fuel amount calculated, which adaptive set value lies at a predetermined level between the rich limit value (M_{F4ST}) and the lean limit value (M_{FK}), after which the adaptive set value (F_{korr}) is compared with the empirically determined amount of fuel (F_{ub}), and when a deviation occurs between these values is the empirically determined amount of fuel corrected proportionally to the deviation between the adaptive set value (F_{korr}) and the empirically determined amount of fuel (F_{ub}).

2. Method according claim 1 c h a r a c t e r i s e d i n that the gradual increase and reduction is interrupted when the rich limit value respectively the lean limit value have been stored, followed by a return sequence to the empirically determined amount of fuel (F_{ub}) or to the corrected amount of fuel which have been corrected dependent of the adaptive set value (F_{korr}).

3. Method according claim 2 c h a r a c t e r i s e d i n that the return sequence to the empirically determined amount of fuel (F_{ub}) or to the corrected amount of fuel which have been corrected dependent of the adaptive set value (F_{korr}), is performed gradually.

4. Method according claim 3 c h a r a c t e r i s e d i n that the gradual return sequence to the empirically determined amount of fuel (F_{ub}) or to the corrected amount of fuel which have been corrected dependent of the adaptive set value (F_{korr}), is performed in increments (ΔFR) of a larger size than the increments performed during the gradual increase(ΔF^+) or reduction (ΔF^-).

5. Method according claim 1 or 4 c h a r a c t e r i s e d i n that the gradual increase or reduction in increments (ΔF^{+} respectively ΔF^{-}) is performed such that each incremental change is maintained during a predetermined number of combustion's (ΔC).

6. Method according claim 5 c h a r a c t e r i s e d i n that the predetermined number of combustion (ΔC) is in the interval 30-100 combustion's, whereby any dynamic effect caused by the incremental change is given time to attenuate properly.

7. Method according any of preceding claims c h a r a c t e r i s e d i n that the four-stroking condition as well as the knocking condition is detected via the spark plug of the combustion engine, by analysing the ionisation current developed in the spark plug gap in a measuring window open during the post-ionisation phase following the break down phase of the ignition voltage.

8. Method according any of preceding claims c h a r a c t e r i s e d i n that the determination of a rich limit value (M_{F4ST}) and a lean limit value (M_{FK}) is initiated when the engine is subjected to a substantially constant load case (steady state) essentially without any changes in speed or load.

9. Method according any of preceding claims c h a r a c t e r i s e d i n that the determination of a rich limit value and a lean limit value is performed a repeatedly number of times during a continuos operating period of the engine, which repetition rate is determined by a predetermined function which will restrict the number of determinations made over a time period, such that the determinations of the lean limit value (M_{FK}) and the rich limit value (M_{F4ST}) is made during fractions of the operating period of the engine, said fractions being below 5% of the total operating period and preferably less than 1% of the total operating period.

10. System for the performance of the method according claim 1 controlling the amount of fuel supplied in two-stroke combustion engines(1) c h a r a c t e r i s e d i n that the fuel control system of the combustion engine includes

- a microprocessor based control unit (3) having a memory (5) containing predetermined amounts of fuel (F) dependent of at least different detected engine speeds and loads (EP), preferably according an empirically determined map or function (F=f (EP)),

-means (7,2) for detecting a knocking condition and means (7,2) for detecting a misfire condition,

-an input data line (11) connected to the fuel control system, at which input data line said means for detecting a knocking condition could deliver at occurrence a signal representative for the knocking condition,

-an input data line (10) connected to the fuel control system, at which input data line said means for detecting a misfire or four-stroking condition could deliver at occurrence a signal representative for the misfire or four-stroking condition,

-means (steps 20-27) for a state responsive initiation of a successive control in the lean direction of the air-fuel ratio supplied, and when a signal representative for a knocking condition occurs at input data line (11) from said means for detecting a knocking condition, allocates a value to a lean limit parameter (M_{FK}) representative for the present amount of fuel supplied, and

-means (step 30-34) for a successive control in the rich direction of the air-fuel ratio supplied, and when a signal representative for a misfire condition occurs at input data line (10) from said means for detecting a misfire or four-stroking condition, allocates a value to a rich limit parameter (M_{F4ST}) representative for the present amount of fuel supplied, and

-arithmetic means, know as such, integrated in the microcomputer, which arithmetic means (step 35-37) calculates a corrected amount of fuel, which corrected amount of fuel is established dependent of a predetermined relative level in relation to the allocated values of the rich limit parameter (M_{F4ST}) and the lean limit parameter (M_{FK}), and where the corrected amount of fuel F_{korr} is substituting the fuel amount given by the empirically determined map (F=f (EP)) during further continuous operation of the engine.

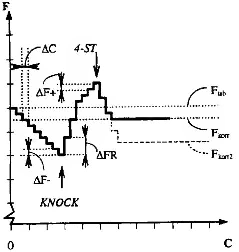
F
ΔC
4-ST
ΔF+
F_{tab}
F_{korr}
F_{korr2}
ΔFR
ΔF-
KNOCK
0
C

FIG.1

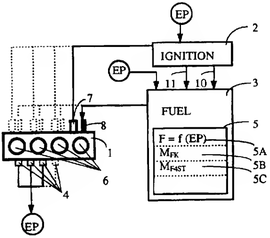
EP
2
IGNITION
EP
11
10
3
7
FUEL
8
5
F = f (EP)
M_{FK}
M_{F4ST}
1
5A
5B
5C
6
4
EP

FIG.3

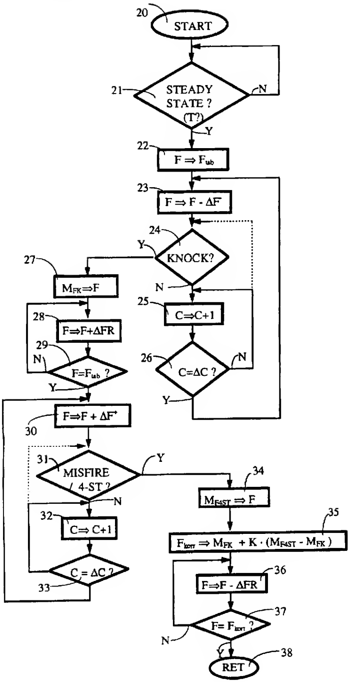
START
STEADY STATE ? (T?)
N
Y
$F \Rightarrow F_{tab}$
$F \Rightarrow F - \Delta F$
KNOCK?
Y
N
$M_{FK} \Rightarrow F$
$C \Rightarrow C+1$
$C = \Delta C$?
$F \Rightarrow F + \Delta FR$
$F = F_{tab}$?
$F \Rightarrow F + \Delta F'$
MISFIRE / 4-ST ?
$M_{F4ST} \Rightarrow F$
$F_{korr} \Rightarrow M_{FK} + K \cdot (M_{F4ST} - M_{FK})$
$C \Rightarrow C+1$
$C = \Delta C$?
$F \Rightarrow F - \Delta FR$
$F = F_{korr}$?
RET
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

FIG.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 95/00915

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F02D 35/02, F02D 41/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CLAIMS, WPI, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4964387 A (HANSEN), 23 October 1990 (23.10.90), abstract --	1,10
A	US 4243009 A (STAERZL), 6 January 1981 (06.01.81), abstract -- --------	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 November 1995	23.11.95
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Erik Torle Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

02/10/95

International application No.
PCT/SE 95/00915

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4964387	23/10/90	NONE	
US-A- 4243009	06/01/81	JP-C- 1451678	25/07/88
		JP-A- 56056948	19/05/81
		JP-B- 62052133	04/11/87